

Rotationally-resolved spectroscopic observations of Phaethon - 2005 UD, and their fragments detected by lunar impact flashes.

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3200 Phaethon is an Apollo type near-Earth asteroid (NEA) categorized as a B-type asteroid which has been associated with the most intense meteor shower, Geminids. Cometary activity of Phaethon has been observed during its perihelion passage, ~ 0.140 AU, that motivates us to do direct exploration by the spacecraft, DESTINY+. It is also suggested that (155140) 2005 UD is a break-up pair of Phaethon because of dynamically similarity and same B-type spectrum type which is only $\sim 5\%$ in NEA population. We examined the spectral properties of this asteroid pair to find the surface heterogeneity. Rotationally-resolved spectroscopic observations of Phaethon were carried out using 1.0-m telescopes at Lulin/Taiwan, and Kawabe/Wakayama, observatories in 2007 and 2017 apparitions, respectively. While Rotationally-resolved spectroscopic observation of 2005 UD was performed by using 4.1-m SOAR telescope at Cerro Tololo, Chili in 2018. It is presumably revealed that the surface heterogeneity, C-type like red slope surface area, of Phaethon was clearly seen from 2017 data, while no-existing surface heterogeneity was observed for 2005 UD.

When a meteoroid impacts the moon at several 10s of km/s, a brilliant flash at the point of impact can be observed as a flash in visible and near-infrared light. Lunar impact monitoring has a great advantage to detect large meteoroids in the mass range between 10s of grams and few kilograms corresponding to centimeters and tens of centimeters, which is as a bridge between visual meteors and small asteroids. We observed lunar impact flashes during Geminids maximum in 2018. 11 events were simultaneously detected from 2 locations at Nihon university and UEC, suggesting existence of relatively large fragments, several cm to several tens of cm in diameter, in the Geminid meteor stream.

In order to understand the Phaethon-Geminid stream Complex (PGC), ground-based telescopic observations of Geminids meteoroids and its parent splitting-bodies will be presented.

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